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Effects of different insecticides on life stages of *Planococcus citri* Risso (Hemiptera: Pseudococcidae)

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Abstract: This study was conducted to detect the effect of some insecticides against different life stages (egg and nymph) of *Planococcus citri* Risso (Hemiptera: Pseudococcidae), a harmful pest on citrus plantations in recent years. Five different active substances (summer oil, Imidacloprid, Chlorpyrifos-ethyl, Buprofezin, Spirotetramat) were used in the study. Abbot and Henderson Tilton analyses were used to evaluate results. All used insecticides had negative effect on hatching of eggs. Buprofezin (68.4%) and Spirotetramat (71.2%) have lesser effect on it than the others. Although summer oil showed its effect shorter time than Imidacloprid and Chlorpyrifos-ethyl, the three insecticides caused 100% mortality on eggs. The number of eggs in eggs masses decreased with Buprofezin (93.0) and Spirotetramat (77.6) compared with the control (110.8). Nymph stage experiments were carried out for seven days. At the end of this period all insecticides caused 100% mortality. All nymphs died within three days for Buprofezin and Chlorpyrifos-ethyl and seven days for summer oil, Imidacloprid and Spirotetramat. When comparing the insecticides, summer oil and chlorpyrifos ethyl look a better control option than the others for citrus mealybug. However, their effects on biological control agents and non-target organism should be determined for a better decision.

Key words: *Planococcus citri*, citrus, pesticide, summer oil, Buprofezin, Chlorpyrifos ethyl, Spirotetramat

Introduction

Citrus production is affected by many pests and diseases in East Mediterranean Region in Turkey. In this region, 89 pests, 17 of them economically important species, have been detected (Uygun and Satar, 2008). Citrus mealybug *Planococcus citri* Risso (Hemiptera: Pseudococcidae) is one of the important pests at citrus orchards (Kansu *et al*., 1980; Uygun *et al*., 2001; Uygun and Satar, 2008). Citrus mealybug is polyphagous and constitutes an important pest on many ornamental plants, citrus and other fruits at greenhouse and nursery at tropical and mild climate (Uygun *et al*., 2008, Goldastes *et al*., 2009). In citrus species, Grapefruit, Washington Navel, Navel orange and lemon are the most preferred species by the pest, respectively.

P. citri is a sporadic pest of citrus, occurring primarily in older, well-shaded groves planted on heavy soils (Kerns, 2012). It decreases fruit quality by sucking at contact points of fruit-stalks, calyx and fruits, and causes fruit drop because of weakening the base of stalks. Additionally, it causes the buildup of honeydew and associated sooty mold fungus on fruits and leaves (Uygun *et al*., 2001). Management of this pest on fruits like citrus and avocado is applied at different points of the world. It can be suppressed successfully by natural enemies or by releasing biological control agents (Singh, 2004, Mahfoudhi *et al*., 2004, Wilson, 1960, Bartlett, 1978, Al *et al*., 2010). On the contrary, when natural balance is damaged by any reason and some climatic factors develop in favor of *P. citri*, biological control is inadequate to suppress the pest. In these circumstances the use of wide spectrum insecticides is inevitable (Bartlett, 1978; Wysoki *et al*., 1981). Thus, if biological control agents and biological balance is altered, heavy infestations of this pest can be observed (Swirsky and Wysoki, 1995).

Citrus mealybug has remained under economic damage for a long time as potential pest at East Mediterranean Region in Turkey. More than 30 biological control agents were reported on this pest in the region (Uygun & Satar, 2008). But, at recent years, as a consequence of upset biological balance, control of pest populations by chemical pesticides has been applied. Integrated pest management methods need to be used at that point. While application of biological control methods at the correct time is important and this method has positive effects on both environment and human health, chemical control is sometimes necessary for sustainable agricultural practices. Commonly, producers use licensed and unlicensed insecticides to control the pest before or after releasing biological control agent. Some of these pesticides are inadequate to control the pest if applied only once and consequently pesticide applications are repeated many times. This situation causes development of resistance to insecticides.

This study was conducted to determine effectiveness of some pesticides commonly used by farmers on the important pest *Planococcus citri*. For this purpose, licensed doses of the insecticides on *P.citri* on citrus and licensed doses on different plants of unlicensed insecticide were tested on egg masses and on the nymph stages.

Material and methods

Insecticides

Commercial formulations were used at the experiments. The organophosphate chlorpyrifos ethyl (Dursban 4-Koruma), the neonicotinoid imidacloprid (Confidor), the cetanol spirotetramat (Movento-Bayer Crop Science), the IGR Buprofezin (Jackpot-Nematec) and summer oil (W-92-Koruma) were tested at the trial. Licensed doses were used at the experiment (Chlorpyrifos ethyl (1 ml/l), spirotetramat (1 ml/l), imidacloprid (0.8 ml/l), Buprofezin (400 g/l) and summer oil (0.012 ml/l)).

***Production of* Planococcus citri**

Planococcus citri was produced on sour orange (*Citrus aurantium* L.) plants 60-70 cm long. Mealybugs were collected on infested citrus orchards at Adana and transferred on the sour orange plants under 25 ± 1 °C temperature and 60 ± 10% humidity conditions at climatic controlled room.

Effect of different insecticides on* Planococcus citri *eggs stage

Planococcus citri egg masses were transferred to the sour orange plants. When the nymphs reached the adult stage were transferred to 30 plants, placing seven to 10 adults per plant. The adults were observed daily for 11 days. 80% of the adults produced their egg masses at the end of the 11 days. The remaining adults were omitted because they could not complete their egg masses. Before insecticide application the egg masses were counted on leaves and each plant had six to eight egg masses.

Plants were separated in six groups, with five replicates planned for each insecticide. A hand sprayer was used for the insecticide applications and water as a control. Before each application, the hand sprayer was cleaned with water and acetone. The number of hatching egg was counted after 24 hours following the application of insecticides and the counting was continued during 30 days.

Effect of different insecticides on egg productivity of **Planococcus citri**

Living individuals after 30 days observation were kept going to monitor. After they become adult and mated, their numbers of eggs in the egg masses were counted to compare different insecticide effect on egg productivity. The experiments were done at 25 ± 1 °C temperature and 60 ± 10% humidity conditions at climatic controlled room.

Effect of different insecticides on Planococcus citri nymph stage

The leaf pieces which have egg masses of *Planococcus citri* were placed on new shouts of the sour orange plants and were provided that finally have 2-3 egg masses per plant. When the mean 15 nymphs were seen on plants, the experiment was established as five repeat for each insecticide. Number of nymph was counted and recorded after 1th, 3rd, 5th and 7th days. Thus, percentage effects of used insecticides on *P. citri* nymphs were detected as comparing with control.

Data analyses

Control dead of egg and nymph experiments were adjusted by using Abbot's formula (1925) and Henderson Tilton analyses, respectively. Percentage mortality values were applied arcsine transformation. To determine the statistical differences was used one way variance analyses. When statistical differences was determined, It was applied multiple comparison test HSD test by SPSS 17 program.

Results and discussion

Effect of different insecticides on Planococcus citri egg stage

The effect of all insecticides on egg hatches was very high. Figure 1 shows two distinct groups. Control is single group. It has a high number of hatching eggs and low mortality. The hatching period continued for nearly 16 days with small fluctuations.

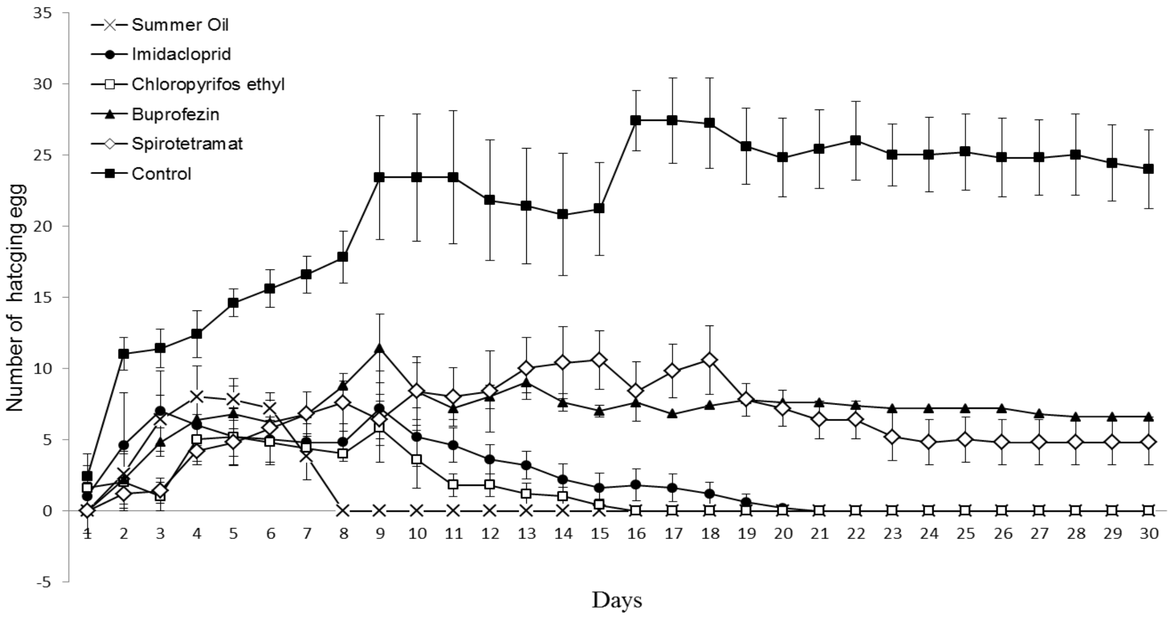

Figure 1. Effect of insecticides which were applied at egg stage on hatched nymphs.

When insecticides were compared, their effectiveness level was different among them. Buprofezin and Spirotetramat produced a similar amount of hatching eggs and both produced lower mortality than the other pesticides tested (Figure 1). Summer oil, Imidacloprid and Chlorpyrifos-ethyl induced lower hatching egg number and caused 100% mortality rate, with summer oil having the quickest effect. Not only the impact of the three insecticides on egg hatching was higher, but also lifetime of individuals that hatched from eggs was shorter.

According to Abbot's formula, Summer oil caused 100% mortality after 14 days differing statistically from the other insecticides except Imidacloprid. Chlorpyrifos-Ethyl had the same effect on mealybug hatched nymphs after 21 days and statistically it is included in the same group with Imidacloprid and summer oil. Buprofezin and Spirotetramat have nearly 70% mortality rate ($df_{3th\ day} = 5, 24$, $F_{3th\ day} = 2.203$, $P_{3th\ day} = 0.087$; $df_{7th\ day} = 5, 24$, $F_{7th\ day} = 13.069$, $P_{7th\ day} = 0.000$; $df_{14th\ day} = 5, 24$, $F_{14th\ day} = 7.718$, $P_{14th\ day} = 0.000$; $df_{21th\ day} = 5, 24$, $F_{21th\ day} = 35.459$, $P_{21th\ day} = 0.000$; $df_{abbot3th\ day} = 4, 20$, $F_{abbot3th\ day} = 0.565$, $P_{abbot3th\ day} = 0.691$; $d_{abbot}f_{7th\ day} = 4, 20$, $F_{abbot7th\ day} = 0.928$, $P_{abbot7th\ day} = 0.468$; $d_{abbot}f_{14th\ day} = 5, 20$, $F_{abbot14th\ day} = 2.642$, $P_{abbot14th\ day} = 0.064$; $df_{abbot21th\ day} = 5, 20$, $F_{abbot21th\ day} = 7.758$, $P_{abbot21th\ day} = 0.001$) (Table 1).

Table 1. Numbers of hatched individuals of *Planococcus citri* after insecticide application as a function of time. Values in column with the same letter do not differ.

Treatment		3.days	7.days	14.days	21.days
Summer Oil	Number of Hatching eggs	6.4±1.72 ab	3.8±1.62 a	0.0±0.00 a	0.0±0.00 a
	Abbot (%)	33.4±22.46	78.1±10.07	100.0±0.00 c	100.0±0.00 b
Imidacloprid	Number of Hatching eggs	7.0±2.81 ab	4.8±1.32 a	1.8±1.20 a	0.2±0.2 a
	Abbot (%)	22.9±37.32	68.1±11.50	91.7±5.07 cb	99.3±0.66 b
Chlorpyrifos-Ethyl	Number of Hatching eggs	4.4±1.43 a	4.6±0.24 a	6.2±2.83 ab	0.0±0.00 a
	Abbot (%)	58.7±11.27	71.9±1.68	66.2±18.1 abc	100.0±0.00 b
Buprofezin	Number of Hatching eggs	4.4±2.77 a	6.8±1.24 a	7.6±3.17 ab	7.6±2.46 b
	Abbot (%)	54.6±31.82	56.7±24.43	56.2±22.01 ab	68.4±9.26 a
Spirotetramat	Number of Hatching eggs	2.6±1.78 a	7.0±1.64 a	10.4±2.54 b	6.2±1.39 b
	Abbot (%)	72.2±21.79	56.6±25.4	45.8±29.52 a	71.2±9.37 a
Control	Number of Hatching eggs	11.4±1.36 b	16.6±1.29 b	21.0±1.61 c	24.8±2.74 c

Effect of different insecticides on egg productivity of Planococcus citri

Living individuals from control, Spirotetramat and buprofezin applications were kept on for observation. Individuals became adults, mated and laid their eggs. The number of eggs in the egg masses was counted and statistically differences were determined between applications. When insecticides were compared, the effect of Spirotetramat on number of laid egg is higher than Buprofezin ($df_{eggy} = 2, 168$, $F_{egg} = 39.942$, $P_{egg} = 0.000$) (Table 2).

Table 2. Number of egg number in egg masses of *Planococcus citri* laid by surviving individuals from Spirotetramat and buprofezin applications.

Treatment	N	Mean of egg number
Buprofezin	35	93.0±3.12 b
Spirotetramat	24	77.6±3.32 a
Control	113	110.8±1.75 c

Effect of different insecticides on* Planococcus citri *nymph stage

P. citri nymphs were observed during seven days and the number of dead *P. citri* nymphs was recorded. At the end of this period all nymphs died except for summer oil and control. Statistical difference was determined between insecticide applications after correction by Henderson Tilton. While Chlorpyrifos-ethyl and Buprofezin applications caused 100% mortality within three days, Imidacloprid and Spirotetramat reached it within 7 days. Thus, Chlorpyrifos-ethyl and Buprofezin have quicker effect on *P.citri* nymphs than the other insecticides ($df_{bef.treatment} = 5, 24$, $F_{bef.treatment} = 0.349$, $P_{bef.treatmenty} = 0.878$; $df_{1\ hour} = 5, 24$, $F_{1\ hour} = 0.981$, $P_{1\ hour} = 0.449$; $df_{1th\ day} = 5, 24$, $F_{1th\ day} = 8.829$, $P_{1th\ day} = 0.000$; $df_{3th\ day} = 5, 24$, $F_{3th\ day} = 30.969$, $P_{3th\ day} = 0.000$; $df_{5th\ day} = 5, 24$, $F_{5th\ day} = 44.444$, $P_{5th\ day} = 0.000$; $df_{7th\ day} = 5, 24$, $F_{7th\ day} = 54.418$, $P_{7th\ day} = 0.000$; $df_{\%survived\ 1\ hour} = 5, 24$, $F_{\%\ survived\ 1\ hour} = 3.492$, $P_{\%\ survived\ 1\ hour} = 0.016$; $df_{\%\ survived\ 1th\ day} = 5, 24$, $F_{\%\ survived\ 1th\ day} = 14.719$, $P_{\%m\ survived\ 1th\ day} = 0.000$; $df_{\%\ survived\ 3th\ day} = 5, 24$, $F_{\%\ survived\ 3th\ day} = 134.625$, $P_{\%\ survived\ 3th\ day} = 0.000$; $df_{\%\ survived\ 5th\ day} = 5, 24$, $F_{\%\ survived\ 5th\ day} = 624.773$, $P_{\%\ survived\ 5th\ day} = 0.000$; $df_{\%\ survived\ 7th\ day} = 5, 24$, $F_{\%\ survived\ 7th\ day} = 1593.709$, $P_{\%\ survived\ 7th\ day} = 0.000$; $df_{Han.til.1\ hour} = 4, 20$, $F_{Han.til.1\ hour} = 1.329$, $P_{Han.til.1\ hour} = 0.293$; $df_{Han.til.1th\ day} = 4, 20$, $F_{Han.til.1th\ day} = 1.286$, $P_{Han.til.1th\ day} = 0.309$; $df_{Han.til.3th\ day} = 4, 20$, $F_{Han.til.3th\ day} = 2.803$, $P_{Han.til.3th\ day} = 0.054$; $df_{Han.til.5th\ day} = 4, 20$, $F_{Han.til.5th\ day} = 1.539$, $P_{Han.til.5th\ day} = 0.229$; $df_{Han.til.7th\ day} = 4, 20$, $F_{Han.til.7th\ day} = 1.000$, $P_{Han.til.7th\ day} = 0.431$) (Table 3).

Discussion

Bio-efficiency studies show summer oil, chlorpyrifos ethyl and imidacloprid as having the highest impact on the egg stage of *P. citri*. Buprofezin and spirotetramat have a lower effect on egg stage. Although these two insecticides are less effective than the others at the egg stage, spirotetramat is less harmful to natural enemies and thus can be more effective in suppressing the pest by applying it a second time or together with natural enemy releases (Satar *et al*., 2011; Karacaoğlu & Satar, 2010; Şimşek *et al*., 2012b). All chemicals tested caused 100% mortality on mealybug nymphs. But it should not be forgotten than these applications were made directly on *P. citri* eggs and nymphs. When chemicals are used under field conditions their effect can be lower because *P. citri* hides under calix or/and between touching fruits. Bhatti *et al*. (1975) reported that Carbaryl is effective on *Phenacoccus insolitus*. Profenophos and triazophos caused high mortality rate on *Ferrisisa virgata* Cockerell (Atodaria, 1998), and *Phenacoccus solenopsis* Tinsley (Nikam *et al*., 2010) in laboratory conditions. Spirotetramat and buprofezin look more effective on the nymph stage than on eggs. These two chemicals could be applied after egg hatching of citrus mealybugs.

Table 3. Living individual change of *Planococcus citri* at nymph stage depending on time after insecticide application.

Treatment		Before treatment	1 hour	1th day	3rd day	5th day	7th day
Summer Oil	Number of Survived individual	14.4±3.32	11.4±2.74	5.6±1.69 a	2.4±1.03 a	0.8±0.58 a	0.2±0.20 a
	% Survived		80.6±7.68 ab	49.1±14.79 a	21.98±11.60 a	8.37±7.33 a	2.5±2.50 a
	% Effect Henderson Tilton		17.7±6.70	47.2±15.88	76.0.0±12.64	90.7±8.05	96.9±3.05
Imidacloprid	Number of Survived individual	18.8±5.12	16.8±5.86	7.4±1.86 a	1.8±0.80 a	0.2±0.20 a	0.0±0.00 a
	% Survived		82.0±7.56 ab	40.3±1.22 a	16.4±7.46 a	1.7±1.67 a	0.0±0.00 a
	% Effect Henderson Tilton		16.0±6.79	56.4±2.98	81.4±8.56	98.1±1.84	100.0±0.00
Chlorpyrifos-Ethyl	Number of Survived individual	14.8±1.62	9.8±1.36	4.8±0.86 a	0.0±0.00 a	0.0±0.00 a	0.0±0.00 a
	% Survived		66.2±6.20 a	34.2±7.80 a	0.0±0.00 a	0.0±0.00 a	0.0±0.00 a
	% Effect Henderson Tilton		31.4±8.03	61.9±10.12	100.0±0.00	100.0±0.00	100.0±0.00
Buprofezin	Number of Survived individual	14.6±2.06	9.6±1.63	3.4±0.75 a	0.0±0.00 a	0.0±0.00 a	0.0±0.00 a
	% Survived		64.9±3.66 a	22.9±3.19 a	0.0±0.00 a	0.0±0.00 a	0.0±0.00 a
	% Effect Henderson Tilton		33.2±4.33	75.5±3.13	100.0±0.00	100.0±0.00	100.0±0.00
Spirotetramat	Number of Survived individual	14.2±2.11	11.6±2.31	4.4±0.51 a	2.6±0.40 a	1.4±0.51 a	0.0±0.00 a
	% Survived		81.6±8.93 ab	34.6±6.94 a	18.3±1.82 a	8.7±3.10 a	0.0±0.00 a
	% Effect Henderson Tilton		15.5±10.69	63.3±6.70	80.2±2.40	89.9±3.81	100.0±0.00
Control	Number of Survived individual	16.0±2.02	15.6±2.06	15.0±2.10 b	15.0±2.10 b	14.4±1.94 b	13.8±1.85 b
	% Survived		0.9±0.02 b	0.8±0.26 b	0.83±0.02 b	0.81±0.02 b	0.78±0.41 b

Summer oil looks the best solution for mealybug control. But the summer period is very hot and sunny in Adana area and farmers generally don't want to use oil because of its high phytotoxic effect. Early applications of oil at February to May once year may be reconsidered by farmers. Chlorpyrifos ethyl is another strong option, but its harmful effect on non-target organism was proved by many studies (Satar *et al*., 2011; Karacaoğlu & Satar. 2010; Şimşek *et al*., 2012a; Şimşek *et al*., 2012b). Chemical control of agricultural pest populations could have enormous side effects on all kind of organisms including man, wild life and non-target species. Lack of beneficial arthropods cause outbreak of secondary pest population and citrus mealybug is one of these pests. Therefore, before using or advice these insecticides their effect on non-target organism has to be considered.

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